Safety
Prevention in Industry

Alberta

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Eye Injury Prevention in Industry

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Summary

Eye injuries occur in industry because the hazards are so rapidly occuring or so severe that natural protective mechanisms are inadequate. While the majority of injuries are of a minor nature, many are more serious. In these cases, the loss to the injured worker may be enormous, while the cost to industry and to society is often very great.

Most eye injuries could be prevented by the constant use of appropriate safety glasses or shields. The Canadian Standards Association publishes a handbook entitled "Eye Protectors" C.S.A. Standard Z 94.3 - 1969 which gives a brief but comprehensive condensed guide to the selection of appropriate frames, lens materials and optical filters for a wide range of industrial tasks.

Frames and lenses which are claimed by manufacturers to meet the required standards are identified by stamped or engraved marks. The Canada Safety Council publishes a list of these identifying marks.

The choice of frames depends on the work task. Selection may be made from C.S.A. tables or from a Hazard Analysis as outlined in this text. Whether the protective lenses set into the frames are of glass or plastic is open to individual choice provided that they meet the requirements for strength set out in the C.S.A. standard.

Whilst providing protection from mechanical and splash injuries, safety glasses also provide protection from radiation. The shade of filter to be used in safety lenses is determined by the type of hazardous radiation. Tables in the C.S.A. standard may be used to guide selection but give no further explanation. A section of this manual is therefore included outlining the types of hazardous radiations and their industrial occurrence.

Vision Safety Programmes in Industry require active promotion and support from management. In such Programmes, it is essential to pay attention to those factors which encourage the worker to comply with safety measures and to reduce non-compliance to a minimum.

Occupational Safety Officers and Nurses are sometimes involved in pre-employment examinations. Since there is

evidence that defective vision contributes to both general and ocular accidents, the identification of defective vision characteristics for different tasks becomes important. The visual demands of work tasks are estimated by Job Vision Analyses. Screening programmes may then be introduced to identify those workers whose visual function may not meet the required standards. Since professional judgement is often involved in these decisions, it may be necessary during these stages to consult an optometrist or an ophthalmologist.

Finally the working environment should be reviewed, particularly in relation to lighting and lighting defects. While this may be expected to reduce accidents, it should also increase productivity. Within the working environment, attention may also be directed to the proper shielding of machines and power tools, to proper and safe ways of handling these machines, and to the ergonomic aspects of the design of visual gauges and readout systems and the arrangement of controls.

Four Appendices are added in this handbook. The first presents the Canadian Safety Council list of identification marks referred to above; the second discusses the evaluation of screening programmes; the third, contact lenses in industry; and the fourth, colour in industry.

Introduction

Much has been written on Occupational Vision Care. Indeed it was the eye problems of sewer workers in the 17th century which first drew the attention of Ramazzini, the "Father of Industrial Medicine", to the immense problem of occupational disease (1).

It is estimated that the annual cost of occupational accidents in the United States exceeds $11.5 billion dollars. On a proportional basis, a Canadian estimate could approach $1.1 billion. This estimate measured against the relatively small costs of safety programmes provides a striking contrast. Where a pair of impact resistant glasses may cost from three to fifteen dollars, compensation costs for a lost eye may range from 5,000 to 20,000 dollars (2).

The hidden or indirect costs of industrial eye accidents are as much as four times the direct cost of compensation and medical service. Even trivial eye injuries causing no permanent damage are costly in production time, first aid costs and so on (3).

A large literature deals with ocular injuries and eye protection. Less has been written on visual performance or on matching visual capacity with the requirements of the job. Both aspects of industrial eye safety are reviewed in this handbook, where optometric and ophthalmological literature has been brought together to provide a reference guide for those involved in occupational health and safety. This handbook is not intended to replace the Canadian Standards Association Z 94.3 - 1969 on Eye Protectors (4), but to be used as an explanatory supplement to that publication.

Ocular Hazards in Industry and the Natural Defenses of the Eye

Ocular Hazards in Industry

Whilst all attempts to classify industrial eye hazards are similar, no standardised classification is accepted (3, 5, 6, 7, 8). Since this handbook is intended as a supplement to the Canadian Standards Association publication (4) we have adopted their classification. One area has been slightly expanded - that of mechanical hazards - because it is important to distinguish between high speed or large objects likely to rupture the globe of the eye, and low speed particles likely to produce only surface injuries. The resulting classification is shown in Table I.

Natural Defenses of the Eye

The human eye has anatomical and physiological protective mechanisms which are extremely effective in day-by-day living. However, in the industrial setting hazards are often so rapidly occurring or so severe that natural mechanisms are inadequate. External protection then becomes essential.

The natural defenses of the eye have been listed, for example, by Collin (8) as follows:

Bony Structures Surrounding the Eye

Very large objects are prevented from striking the eye by the strong bony ridges under the eyebrow and the cheek. However, smaller objects the size of a fist or tennis ball can strike the eyeball from the front and obliquely from the side without contacting bone. Thus, the bony rim of the eye socket provides little protection in most industrial injuries.

The Eyelids

Provided the blink reflex occurs in time, the eyelids protect the eye from injury by liquid splash, low velocity particles and dust. However in many industrial injuries, particles are too small or are moving too rapidly for the lids to have time to close, and in some cases very fast moving particles, such as are ejected from a hammer striking a burred chisel, may pass completely through the eyelids to penetrate the eyeball.

TABLE I

HAZARD GROUP	PROTECTION AGAINST	EFFECT
A.	Large or high velocity flying objects or fragments.	Major damage to or penetration of the eye.
	Small low speed flying particles.	Non-penetrating surface foreign bodies.
B.	Flying particles, dust, wind, etc.	Surface foreign bodies and irritation.
C.	Heat, glare, sparks and splash from molten metal.	Minor to major eyelid and eye burns. Surface foreign bodies.
D.	Acid splash, chemical burns, etc.	Mild to severe surface and deep injuries.
E.	Abrasive blasting materials.	Surface foreign bodies.
F.	Glare, stray light (lightly tinted glasses needed).	See section on radiation protection.
G.	Injurious radiation. (moderately tinted glasses needed)	"Arc eye". Lens damage.
H.	Injurious radiation. (densely tinted glass needed)	"Arc eye".

WORK EXAMPLES

Chipping, scaling, stonework, nail guns, explosive charges, heavy sawing, planing, hammering on brittle steels. High pressure hoses and lines.

Grinding, buffing, polishing. Rivetting, punching, shearing, lathework.

Woodworking, sanding, turning, light metal work and machining, exposure to dust and wind, grain, cement and coal handling.

Babitting, pouring, casting. Hot dipping operations. Brazing. Spot welding.

Acid and alkali handling. Degreasing and plating operations. Liquid splash from glass breakage.

Sand and shot blasting.

Reflection, bright sun and lights. Reflected welding flash. Metal pouring and furnace work. Spot welding.

Gas cutting and welding. Furnace work.

Electric arc. Heavy gas cutting. Complex forms of welding.

TABLE II

	HAZARD	POSSIBLE NATURAL DEFENSE
Mechanical	- Large or very high velocity flying fragments and objects	Bony structure surrounding the eye Eyelids
	- Small low speed flying particles	Bony structure surrounding the eye Eyelids
	- Dusts, powders, and winds	Tears Eyelids
	- Splashing metal, sparks, heat	Eyelids
Chemical	- Liquids and Corrosives	Tears Eyelids
	- Gases, vapours, and fumes	Eyelids to some extent Tears to some extent
Radiation	- Microwaves and infra-red	Eyelids
	- Ultra violet	
	- Ionizing	

DEFENSES EFFECTIVENESS	ADDITIONAL PROTECTION REQUIRED
Limited defense from frontal approach Blink reflex too slow	Spectacles with side shields.
No defense from frontal approach Blink reflex too slow	Spectacles with side shields
Tears cannot flush away all particles Blink reflex too slow	Goggles - regular or hooded, ventilation
Blink reflex too slow	Goggles - mostly hooded, ventilation
Tears do not provide adequate dilution Eyelids provide only a partial barrier	Goggles - regular or hooded, ventilation
No adequate defense Total protection needed	Goggles - mostly hooded, ventilation
No Defenses	spectacles, goggles, masks - general or specific wavelength attenuation properties

The Cornea

The cornea is the clear window covering the front of the eye. It is exquisitely sensitive to touch which immediately initiates both the blink reflex and a copious flow of tears. The protective function of reflex tearing is obvious, but is quite inadequate to wash away or dilute industrial chemicals such as caustics or strong acids which cause extensive damage. Dilute acids and alcohol or other organic solvents usually cause only corneal surface abrasions.

Whereas the cornea has little protection from chemical splash, it has great mechanical strength and is rarely perforated. The majority of foreign bodies such as arise from grinding, scaling and small swarfs from lathe work scarcely penetrate the surface and are easily removed.

In summary, in the occupational setting, where risks are high and where hazards are often more violent than those for which the protective mechanisms have evolved, additional protection is needed. In Table II, the hazards (using a more generalized classification), the natural protective mechanisms, and the additional protection needed are summarized.

Standards for Protective Eyewear

As accident statistics show, the natural protective mechanisms of the eye are inadequate in the industrial setting and workers' eyes are at risk. What can be done? Three approaches are possible:

1. Machines, instruments, and the working environment may be modified to remove or reduce the hazard.
2. The workers' skills may be improved to reduce the hazard.
3. Protective screens, goggles or spectacles may be worn to prevent harm from the hazard.

In this and the succeeding two sections, protective eyewear is discussed. Standards for equipment and the choice of lens materials are first described. The next section deals with the choice of frames and mechanical supports, and the third section with the choice of optical filters in the lenses.

Standards for Equipment and the Choice of Lens Materials

The Canadian Standards Association (C.S.A.) and the American National Standards Institute (A.N.S.I.) publish standards and guidelines for eye protection devices. The C.S.A. standard is Z 94.3 - 1969 and the American standard is Z 87.1 - 1968.

All eye protection devices used in Canada should meet the C.S.A. standard. Manufacturers claiming to meet these standards must stamp on the frame and on the lens an identification trademark or name. A copy of the Eye Protection Identification List produced by the Canada Safety Council is given in Appendix A.

Whether the lens is made of toughened glass or of plastic is left open to choice, given a few practical considerations. The performance standards for each type of lens material are absolutely specific, and are given in the C.S.A. standard (4) as Table 2 on Page 20 of that document. Centre thickness, fracture resistance, penetration resistance by a dropped needle and required markings are all specified.

A question arises whether commercially available products truly meet these specifications. A useful sampling study was

performed by Kamin (9) who tested commercial safety eyewear against the A.N.S.I. standards. He showed that, in general, materials manufactured in the U.S.A. meet these high standards. Although few tests of this kind are available for materials manufactured in Canada, there is no reason to assume any less quality.

A good safety lens, in addition to meeting C.S.A. standards, should have two characteristics:

1. Good optical quality.
2. Scratch resistance.

Glass lenses have remained as the preferred safety lens. They have good optical qualities, are not easily scratched, and can be tempered to withstand the required impact tests. On the other hand, they are heavier than plastic particularly where the worker requires a strong spectacle correction built into his eye protection.

Plastic is optically excellent, light weight, and extremely impact resistant. Its disadvantages are that it costs more, that improper fitting into the frame can cause distortions, and that it is readily scratched, a problem which is being overcome by the use of special coatings to protect the lens surface.

Studies comparing glass and plastic lenses are available in the work of Wigglesworth (10). Although 3mm thermally toughened glass had superior resistance to the impact of very large (1" diameter) missiles at low velocity, it was inferior to all the optically acceptable plastics under the impact of smaller missiles (¼" diameter and less) at high velocity. His studies showed that materials with high impact resistance (plastic) have lower hardness values and hence lower scratch resistance when compared with glass and he concluded that no completely suitable material is currently available. Whether to use glass or plastic lenses is thus a matter of personal choice.

Frames, Goggles and Shields

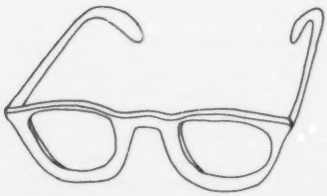
In addition to setting standards of manufacture for protective lenses, the Standards Associations give guidelines for the selection of appropriate supports and frames. Catalogues of

firms specializing in the supply of safety equipment classify their products under the same headings as the Standards Associations, and the salesmen of such companies should be entirely familiar with their applications.

The different types of supports and frames are described as follows, the illustrations being taken directly from the C.S.A. standards:

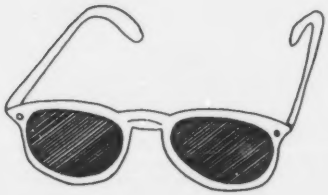
Class 1 - Safety Spectacles

The most commonly worn of all the eye safety protection devices. These consist of safety lenses in a special frame which supports the lenses around their entire periphery. Safety spectacles are commonly used with side shields.

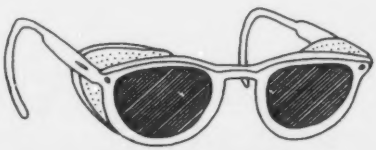


Class 1 (a)
Spectacles Without Side Shields

Class 1 (b)
Spectacles With Side Shields



Class 1 (c)



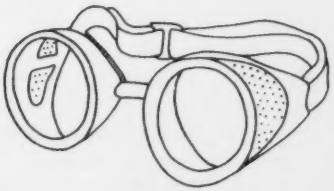
Class 1 (d)

Class 2 - Eye Cup Goggles

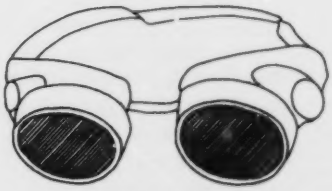
Consist of two eye cups, with lenses and lens retainers connected by an adjustable bridge, and a replaceable and adjustable headband for retaining the eye cups comfortably in front of the eyes. They can be designed for those who do not wear spectacles and to fit over the spectacles of those who do.

Eye cup goggles are supplied for three purposes, and differ mainly in the type of ventilation provided.

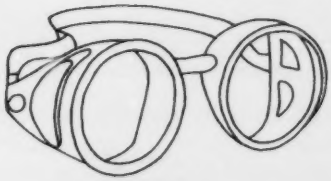
1) Chipper's Models - provide impact protection against flying objects.
2) Dust and Splash Models - provide protection against relatively fine dust particles or liquid splash and impact.
3) Welder's and Cutter's Models - provide protection against glare, injurious radiation, and impact.



Class 2 (a)
Eyecup Goggles for Impact Protection



Class 2 (c)
Eyecup Goggles for Radiation

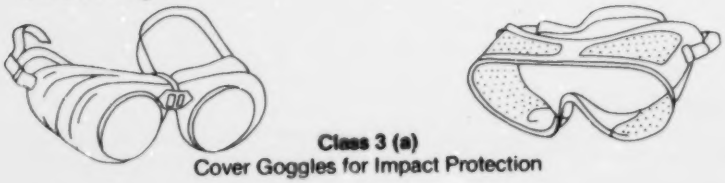


Class 2 (b)
Eyecup Goggles for Dust and Splash

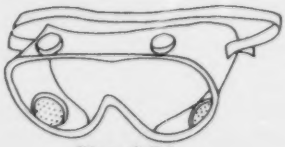
Class 3 - Cover Goggles

Consist of a flexible frame forming a lens holder or a rigid frame with integral lens or lenses, having a separate, cushioned fitting surface on the full periphery of the facial contact area. A headband or other support is required to retain the frame comfortably in place. The goggles may be ventilated if required, but where chemical goggles are ventilated, the openings must be able to render the goggles splashproof. Like eye cup goggles, flexible goggles are subdivided into several models.

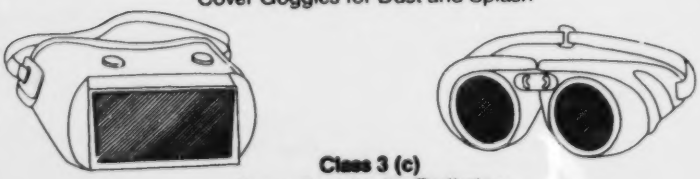
1) Chipper's Models - provide protection against impact.
2) Dust and Splash Models - provide protection from fine dusts, fumes, liquids, splashes, mists and sprays. May also protect from radiation and from impact.
3) Welder's and Cutter's Models - provide protection from glare, injurious radiations, and impact. The frames and lens supports are opaque to the range of ultraviolet, visible and infra-red light.



Class 3 (a)
Cover Goggles for Impact Protection



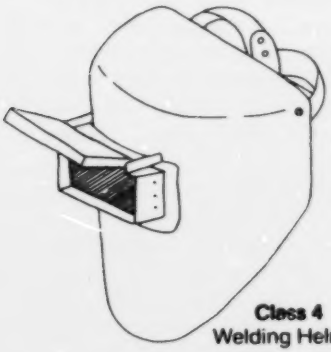
Class 3 (b)
Cover Goggles for Dust and Splash



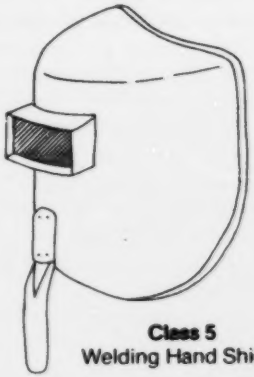
Class 3 (c)
Cover Goggles for Radiation

Class 4 - Welding Helmets and Class 5 - Hand Shields

Designed to provide protection for the eyes, face, ears and neck against intense radiant energy and weld splatter. They are opaque bowl-shaped devices, each containing a window with filter plate which allows viewing but protects the eye from harmful intensities of radiation.



Class 4
Welding Helmet



Class 5
Welding Hand Shield

Class 6 - Face Shields

These are devices designed to provide protection to the face and neck from flying particles and sprays of hazardous liquids and, in addition, to provide antiglare protection where required. Such devices are always worn **in addition** to basic eye protection. Wire mesh grids may be used to provide protection in this group.

Class 6
Face Shield

The choice of protection for most industrial tasks is indicated in the C.S.A. Table I, pages 14 and 15 (4). Whilst Hazard Group A distinguishes those tasks likely to produce a penetrating injury from those likely to produce a surface foreign body injury, the distinction does not affect the choice of eye protection and similar protectors are required for both hazards.

A similar table given by Taylor (6) is reproduced in Table III. This table is important because it lists modifications to the machines and work environment as a means of controlling hazards, and should remind those involved in industrial eye safety to be constantly aware of this area in plant surveys.

If there is any doubt about the appropriate type of protector to use for a given task, perhaps because the task is not specifically listed in the C.S.A. table, then a HAZARD ANALYSIS as described by Hammer (11) should help to make the choice. In this process, the hazard is analysed by its components. A simple example follows:

WELDING	
Small flying particles. Sparks, molten metal. Harmful radiation.	What protector covers all of these hazards? Eyecup goggles or cover goggles with appropriate filters.

Such an approach properly encourages the thoughtful analysis of work hazards and should be thought of as a useful supplement to the application of the C.S.A. table.

In choosing suitable eye protection for industry, the types and quality of frames, goggles and shields have been discussed in this section and the type of lens material in the preceding section. The final choice is that of suitable filters and shades, and is the subject of the next section.

TABLE III

RECOMMENDED METHOD OF INDUSTRIAL EYE PROTECTION

1 HAZARDS TYPE/GROUP	2 TYPICAL PROCESSES GIVING RISE TO SUCH HAZARDS	3 TYPICAL METHODS OF CONTROLLING HAZARDS
A. Flying fragments and objects	Chipping, rivetting, spalling, hammering, handling wire and strip, stone and brick cutting	Fixed or mobile screens
B. Small flying particles	Scaling, grinding and machining metals, certain wood-working operations, stone dressing	Fixed or mobile screens Exhaust systems, dust extractors, water
C. Dusts	Road work, coal handling, textile trades, some chemical works, leather buffing, timber sanding	For indoor work — exhaust systems, dust extractors, suction conveyors For outdoor work — damping down of work area, sealing of dusty surfaces, use of large fixed or mobile screens
D. Splashing metals Splashing materials Corrosives	Overhead cutting and welding, lead jointing, hot bitumen, metal baths, metal cleaning and plating, handling corrosives	Screens, catchments, splashguards, overflows, tilting apparatus and splash trays
E. Harmful liquids, gases and vapours	Chemical processes, spray painting	Suitable screens or baffles, exhaust systems
F. Radiation	Welding, cutting, brazing	Fixed or mobile screens

4

SELECTION OF EYE PROTECTORS

SUITABLE TYPE	NOTES ON SELECTION (See also Rule 4, 3)
General purpose protectors Impact protectors	1. General purpose protectors; where all round protection is required the eye protectors should be provided with side shields.
	2. Safety spectacles, where frontal protection only is required. 3. Face shield, where additional face protection is required. 4. Dust goggles, where additional protection from small particles is required.
Dust goggles, or other types which will exclude dust	5. Use of glass lenses not heat treated is not recommended. 6. Where respiratory protection is needed the eye protection may be incorporated in the respiratory protective device.
General purpose protectors Impact protectors	7. Face shield or a hood incorporating eye protection.
Chemical protectors and gas-tight goggles	8. Face shields. 9. Unventilated types needed for gases and vapours. 10. Where respiratory protection is needed, the eye protection may be incorporated in the respiratory protective device.
Welding goggles, helmet or handshields	

Optical Filters and Radiation Protection

Radiation hazards to furnace workers and glassblowers, where infra-red radiation produced cataracts, provided a classical example of industrial disease. The subject is now of historical interest because modification to the work environment and understanding of the use of goggles has all but eliminated this disease. New hazards arise, however, in particular those from microwave and ionizing radiations, which are of great topical interest. This section is extended therefore to provide background information on the nature of radiation and its hazards. A good review of this topic is given by Newell (12).

Radiant energy is produced by an enormous range of physical phenomena, from the electrical oscillations which give rise to long wavelength radiations used in telecommunication, through the visible radiations usually produced by bodies at high temperatures, to the ionizing radiations of very short wavelength produced by radio-active materials. Radio waves and light (visible radiation) are often considered as electromagnetic radiation, while ionizing radiations are often considered as corpuscular or particulate radiation. In this monograph, these differences are not important and all radiation is considered as radiant energy, differing only in its wavelength and in its effect on human tissues. For an excellent discussion of the physical background for medical and allied workers see Newell (12) and Duke-Elder (13).

All radiant energy can be considered in the form of waves, much as the energy of a stone falling into a pool of water is transmitted to the shore in a series of waves radiating from the centre. The distance between the crests of the waves is the WAVELENGTH.

All radiant energy travels at the same speed. Therefore, only a few waves of long wavelength pass a selected point in a given time, whereas many waves of short wavelength would pass that point. The number of waves passing a point in a given time is the FREQUENCY. Thus long wavelength radiation is low frequency while short wavelength is of high frequency. The radiation from radio-active materials and visible radiations is

usually described according to wavelength. Radiations used in broadcasting are usually described according to frequency. This customary division should not obscure the fact that **all** are forms of radiant energy.

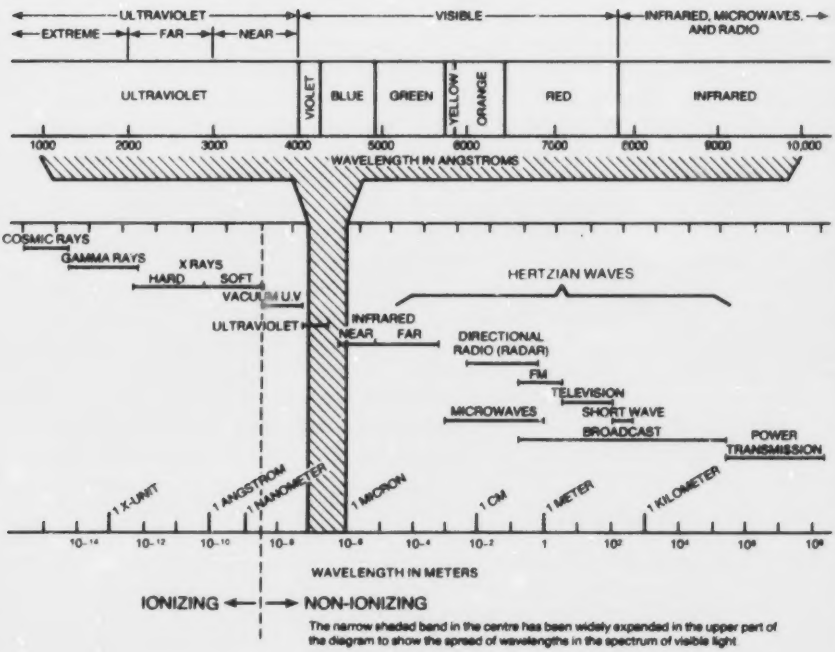
The RANGE OF WAVELENGTHS to be considered in industrial settings is enormous (Fig I). It extends from one one-hundred-million-millionth of a metre to some ten million metres (10^{-14} to 10^{-7} metres). That band of radiant energy giving rise to light, the VISIBLE SPECTRUM, occupies only a tiny portion of this range, from about four ten-millionth parts of a metre to eight ten-millionth parts of a metre (4×10^{-7} to 8×10^{-7} metres).

A second quality of radiant energy to be considered is its intensity or POWER. Power is measured in different ways depending on the wavelength being considered. The intensity of the wavelengths used in telecommunication and radar is measured in WATTS, the electrical power used in setting up the oscillations in the aerials used to produce the radiation* The intensity of the visible wavelengths is usually measured in LUMINOSITY, equivalent to sensations of brightness. The intensity of ionizing radiation is usually measured in RADS which relate to the amount of radiant energy absorbed by the irradiated material.

* Controversy exists on the best measurement of dosage in the biological setting.

FIGURE 1

THE ELECTROMAGNETIC SPECTRUM



The narrow shaded band in the centre has been widely expanded in the upper part of the diagram to show the spread of wavelengths in the spectrum of visible light.

Radiant Energy and the Eye

The effects of radiant energy on the eye are determined by three characteristics:

i) The effect of the particular wavelengths on human tissue cells.

ii) The depth of penetration into the tissues of the eye.

iii) Whether the radiant energy is focussed by the optics of the eye.

In the following sections, the occupational hazards of each group of wavelengths are discussed under each of the three headings.

LOW FREQUENCY RADIATION

Low frequency, long wavelength radiations are used in power and radio transmission.

i) Effect on Tissue Cells
There is no significant effect on tissue cells in the industrial setting since at the powers used, no tissue heating occurs.

ii) Depth of Penetration
Radio waves pass through the body and the eye with hardly any absorption. The body is "transparent" to these radiations.

iii) Effect on Optics of the Eye
The optical components of the eye do not have any focussing effect on radio waves.

LOW FREQUENCY "MICROWAVES"

Microwaves are of shorter wave-length than radio waves and longer than infra-red radiation. They are used in industry in radar power and television transmissions, and domestically in microwave cookers. They are also used in medicine for heating of tissues and for control of bleeding in surgery.

Industrial exposure to microwaves is low compared with the dose required to produce damage in animal experiments. In the few reports discussed by Duke-Elder (13), the evidence that eye damage occurred in man from microwave exposure is slight and contradictory reports comparing exposed and non-exposed workers suggest that there is no significant industrial risk.

Nevertheless, there is a rapidly growing interest and concern in this area (14, 15, 16) and it would be wise for all involved in industrial health and safety to monitor the subject closely. A balanced view of the significance of reports and papers is always difficult. A light-hearted but realistic discussion of the general hazard from microwaves is given by Justesen (17).

i) Effect on Tissue Cells
The effect of microwaves on tissue cells depends on the creation of heat and the accompanying temperature rise, an application which is used in microwave cooking. Experiments have been performed on the eyes of animals exposed to high intensities of microwave radiation showing many different types of damage. Greatest interest centres around changes in the lens where HEAT CATARACT occurs, the mildest forms appearing several weeks after exposure. Whether animal experiments can be applied to man in industry is still controversial, but has led to the establishment of limiting standards for industrial exposure.

ii) Depth of Penetration
The energy of microwaves is absorbed during penetration of body tissue, giving rise to heat (see above).

iii) Effect of the Optics of the Eye
Microwaves are not focussed by the optics of the eye so that there is no concentration of their effect within the eye.

INFRA-RED RADIATION

Infra-red radiations occupy the wavelength range from roughly 15000 to 8000 Angstrom Units*. All warm or hot bodies emit infra-red radiation, a property used extensively in missile tracking and satellite surveillance of the earth. Ocular damage from high levels of exposure to infra-red has long been recognized as an industrial hazard, much of the writing on this topic coming from the 19th century. At that time, workers in glass factories were found to be at considerable risk of

* At these wavelengths, it is usual to express wavelengths in terms of units much smaller than a millimetre. The Angstrom Unit is one ten millionth part of a millimetre.

developing cataracts, as were furnace workers and workers exposed to radiation from molten metals.

These industries are as active as ever but the occurrence of ocular damage has almost entirely disappeared, largely because of changing industrial processes having reduced exposure to the rays. This is as well, since working in these environments is not comfortable and workers have difficulty in wearing protective goggles (13).

i) Effect on Tissue Cells
Infra-red radiation produces damage by localized heating. In industrial cataracts, the heating is low grade and cumulative so that damage to the lens appears only after years of exposure.

ii) Depth of Penetration
The optical components of the eye are not transparent to the whole range of infra-red radiations. Some bands in infra-red are absorbed at the surface, others are absorbed during passage through the eye, while yet others are transmitted to the retina in the same way as the light rays. Whereas the optical parts of the eye are variously transparent to infra-red, the pigmented tissues in the eye absorb all of the infra-red radiation reaching them. For example, the formation of cataracts in furnace workers almost certainly depended on heating of the iris when infra-red radiation was absorbed there, with secondary heating of the lens where the iris and lens were in contact.

iii) Effect of the Optics of the Eye
This is the first group of radiations so far considered which are focussed by the optics of the eye. The result is that those infra-red rays which are transmitted into the eye become tightly focussed, with a great concentration of radiation. Industrial retinal burns with permanent damage are exceptionally rare, although exposure to the transient flash of short-circuiting currents or to welding arcs may produce temporary derangements of vision. The changes in this situation come from visible and infra-red radiations, not from the infra-red alone.

THE VISIBLE SPECTRUM

Radiations giving rise to sight occupy the wavelength band from approximately 7000 to 4000 Angstroms. Very high intensity accurately focussed light radiation has been extensively used in the medical management of disease of the retina, and has now been displaced by the use of LASERS for the same purpose. Industrial hazard from lasers is discussed later.

i) Effect on Tissue Cells

Visible radiations when high power tightly focussed beams are used produce damage by intense localized heating. The light is absorbed by pigmented tissues within the eye, especially the retinal pigment epithelium, and is there converted to heat.

ii) Depth of Penetration

Visible radiations pass through the transparent tissues of the eye to reach the retina where they are absorbed as noted in section 1.

iii) Effect of Optics of the Eye

Obviously visible rays are accurately focussed by the eye to give clear retinal images.

ULTRA-VIOLET RADIATION

Ultra-violet radiations extend from about 4000 Angstroms to some 140 Angstroms in wavelength. Industrial exposure is common. Ultra-violet radiation alone is used in "sun-ray" treatment and in other medical applications. Modern photocopying machines use light rich in ultra-violet but the commonest exposure occurs where visible light richly mixed with ultra-violet radiation is projected in oxyacetylene and arc welding and in arc furnaces. This is said to be the commonest of all accidents in engineering shops (13). The effects of repeated exposure of low intensity tend to be cumulative over a few hours, and low doses can therefore produce damage if repeated. It is possible for radiation from the welding arc of another person some distance away to affect the eyes of a welder if the light shines around the side of his welding shield.

i) Effect on Tissue Cells

In the radiations previously discussed, absorption of

radiation led to local tissue heating. In contrast, when absorbed within the cell, ultra-violet radiation leads to alterations of the molecules themselves, a so-called ABIOTIC reaction. The reactions of irradiated cells are well known, two characteristics being especially important. First, there is a long latent period of 6 to 8 hours between exposure and onset of symptoms. Second, tissues heal very rapidly indeed, either the cells themselves recovering or, if individual cells are destroyed, the adjacent cells filling the gaps.

All wavelengths in the ultra-violet band are not equally effective in producing tissue damage. Maximum damage occurs somewhere in the middle of the range at about 3000 Angstroms.

ii) Depth of Penetration

Because most ultra-violet radiation is absorbed at the surface, while the longer wavelengths in the band, to which the eye is relatively transparent, are of very weak abiotic (damaging) potential, the major site of damage is in the top few layers of the surface epithelium covering the cornea. When an eye is exposed to ultra-violet radiation, the lens can be seen to fluoresce, indicating penetration of some of the rays at least this far. However, it is **extremely** doubtful whether ultra-violet radiation has any harmful effect in the eye apart from its effect on the corneal epithelium. The position is summarized by Duke-Elder (13) "... it is probably safe to say that the ultra-violet radiations which might harm the retina do not reach it, and that those radiations of this spectral region which do reach it, have not been shown to do organic or functional harm of any practical importance to this tissue."

LASER LIGHT

Laser light is a very intense coherent type of light of great power which is monochromatic, that is, of a single wavelength only. Many different types of laser exist, each producing its own frequency. For example, the Carbon Dioxide laser produces beams in the infra-red wavelengths at 10600 Angstroms, outside the visible spectrum, the Ruby laser in the visible spectrum

around 7000 Angstroms, and the Argon laser in several wavelength bands around 5000 Angstroms.

Lasers have enormously wide industrial and medical applications. They are used extensively in military and space work, in communications, and in the medical management of many retinal diseases.

i) Effect on Tissue Cells
When laser light is absorbed by tissues, heat is produced causing a rise in temperature. Tissue damage results, and may be extremely localized because of the focussing effects of the eye (see below).

ii) Depth of Penetration
As might be expected, depth of penetration depends on wavelength. Carbon Dioxide laser radiation is absorbed by the cornea, producing corneal but no retinal damage. Ruby and Argon laser light is transmitted through the transparent ocular tissues, but is of course absorbed by iris or retinal tissues.

iii) Effect of the Optics of the Eye
Laser radiation transmitted by the optical tissues in the eye is focussed onto the retina. For this reason, extremely accurate and localized retinal burns are possible in medical applications.

IONIZING RADIATIONS

Ionizing radiations cover a wide range of wavelengths, from 140 Angstroms to one ten-millionth part of an Angstrom unit. The radiations have different names, for example, beta-radiation, gamma-radiation and x-rays; and some are thought of as particulate while others are considered electro-magnetic. As has been discussed above, all are here considered as electro-magnetic, differing only in their penetrating power and their effectiveness in producing a common radiational injury.

Modern industrial uses of ionizing radiation are widespread. Over 300 uses have been listed. Hazards of exposure to ionizing radiations are of topical interest in relation to medical and to power generating plant applications.

i) Effect on Tissue Cells
Tissue damage results from destruction of the cells due to IONIZATION. Early effects are seen microscopically as changes within cells and changes in their blood supply. Late stages are very diverse, and include both general illness such as leukemia, or local ocular change such as cataract. Other injuries occur with more severe exposure and are discussed by Duke-Elder (13). In the eye, the classical industrial radition hazard is CATARACT.

ii) Depth of Penetration
This depends on the power of the radiation and upon its type. For example, beta radiation penetrates very little while x-rays and gamma rays penetrate deeply.

iii) Effect of the Optics of the Eye
Ionizing radiations are not focussed by the optics of the eye.

Protection from Radiation Hazards

The best way to protect against any industrial hazard is to eliminate it from the job area. Glass blower's cataract is now only a curiosity because advancing technology eliminated the exposure of workers in that industry.

Where this is not possible, adaptations to the job site may shield the workers from exposure. Microwave protection is usually achieved by shielding of equipment and, as in the case of domestic microwave ovens, by ensuring that radiation leakage from the devices is well within accepted limits. In hospital x-ray departments where the workers are shielded from radiation whilst diagnostic or therapeutic exposures are made, or in the industrial use of lasers (which are becoming more and more numerous) where the worker should be protected from exposure to direct or reflected laser beams of damaging intensity, the same approach is used.

Where this approach is not possible, and particularly for those radiations which are close to the visible spectrum (infra-red and ultra-violet) protective eye cover must be used. The basis of radiation protection is to reduce the intensity of damaging radiation to harmless levels while at the same time allowing

sufficient light to pass so that the worker can see his job properly.

Therefore, the use of spectacles which selectively absorb certain wavelengths while transmitting others is recommended. Such lenses are generally a mixture of glass and a metallic oxide, ferrous oxide being used to absorb infra-red and cerium oxide to absorb ultra-violet. Partially reflecting lenses are also manufactured to protect from potentially harmful radiation.

Choice of Optical Filters

The C.S.A. Standard Z 94.3 - 1969, shows the requirements for absorptive lenses used in industry (4). Safety lenses and safety glass for industrial use are manufactured to these standards under different trade names and are carried by the safety supply houses (see Appendix A).

Cost comparison may lead industries to select one trade name over the other and this must be a matter of individual choice. In this handbook, it seems most appropriate to explain the significance of the terms used in the C.S.A. Table so that safety officers and purchasers may check manufacturers' claims against the standards.

TRANSMITTANCE is the ratio of the light intensity emerging from the back of the lens to that falling on the front of the lens. Thus, a totally opaque lens would have a transmittance of 0 and a perfectly transparent one of 1. Since there is no perfectly transparent material, transmittance is always less than 1. The OPACITY of a glass is the inverse of its transmittance, that is, the ratio of the light incident on the lens to the light emerging from the lens. Thus a lens which had a TRANSMITTANCE of 0.5 would have an OPACITY of 2, i.e. twice as much light falls on the lens as passes through it.

Why use the term opacity at all when transmittance is so easily understood? In order to calculate the effect of a series of filters, it is necessary to multiply together the transmittances or opacities of each filter. However, if an exponential relation ($\log_{10}$opacity) is used to define the attenuating property of the filters, then the effect of a series of filters is calculated by simple addition of the logs. The $\log_{10}$opacity is called the OPTICAL

DENSITY. The following table should clarify the above.

INCIDENT LIGHT	EMERGENT LIGHT	TRANSMITTANCE	OPACITY	OPTICAL DENSITY
2	1	0.5	2.0	0.3 ($\log_{10}2$)
10	1	0.1	10.0	1.0 ($\log_{10}10$)
20	1	0.05	20.0	1.3 ($\log_{10}20$)
100	1	0.01	100.0	2.0 ($\log_{10}100$)
400	1	0.0025	400.0	2.6 ($\log_{10}400$)
1000	1	0.001	1000.0	3.0 ($\log_{10}1000$)

One more definition is required in relation to filters. As the C.S.A. Table shows, filter lenses are also classified by SHADE NUMBER defined as (7/3 × optical density) +1.

Other aspects of the C.S.A. Table needing clarification are as follows:

A. Density and Transmittance ranges specified are for a particular standard illumination source (C.S.A. Z 94.3 - 1969).

B. The maximum total heat transmittance, which relates to infra-red rays, uses a standard tungsten filament lamp at a standard white heat temperature (C.S.A. Z 94.3 - 1969).

Summary on Optical Filters

Optical filters are used to protect workers from damaging radiations in the visible, infra-red and ultra-violet ranges. They are required to reduce the undesired radiation to negligible or harmless amounts whilst allowing enough light to pass for visibility. The standards and densities for filtering glass are well defined in the C.S.A. Handbook (4).

Protection from lasers is usually accomplished by avoidance of exposure, and by taking particular care over reflected beams. The same avoidance of exposure applies to protection from microwaves and from x-rays and related radiations. In these cases, modifications of both the machines and of the workers' behaviour should ensure that exposures are kept well within safe limits as known at the time.

The Vision Safety Programme

There are three cornerstones in industrial eye protection; the protective devices themselves, the promotion of their use by management, and the compliance of the worker. The subjects so far discussed have concentrated on eye protection. In this section, both Industrial Vision Conservation Programmes and worker compliance are covered.

General Components

The essential components of a Vision Care Programme in industry are as follows (18):

1. Commitment from management with a policy statement.
2. Plant Survey and Job Vision Analysis initiated by management, examining all areas which could have a bearing on the program. These include production procedures, plant discipline, use of safety equipment, lighting, eye hazards, plant layout, eye injury experience and so on.
3. Development of Vision Standards in each job and selection of appropriate eye protection devices.
4. Vision Screening with appropriate referral can now take place (see Fig. 3, Page 48).
5. Fitting of Appropriate Eye Protection
6. Evaluation by comparison of present production and safety objectives and records with those before the program began.

The detailed description of each component is not further discussed here. Job Vision Analysis, development of Vision Standards, and Vision Screening form the subject of later chapters, and the general format of the programme follows common sense principles. For more details, the reader is referred to a series of articles in the Australian Journal of Optometry (19) and an article by Magyar (20).

Compliance

The task of establishing an eye protection programme is futile if the worker will not comply with the wearing of eye protection. This subject of "compliance" has developed a large literature, most of it relating to medical treatment, but the problem is of

equal importance in many other areas.

When considering worker's compliance with eye safety programmes, particular attention should be paid to the following factors:

Attitudes

Compliance obviously results from the dominance of a positive over a negative attitude. Attitudes form the basis upon which motivation grows, and usually have a strong emotional component. Attitudes are developed in many ways, for example:

a. by peer pressure.
b. by personal beliefs.
c. by lack of faith in usefulness of eye protection.
d. by bad experience with eye protection which was difficult to use.

Motivation

Improvement in compliance, depending on changing attitudes, requires the creation of motivation. It is easier to attain if there is constant concern about and knowledge of eye safety in the factory. This constant drive towards a learning process is vital to the development of compliance in all industrial workers. Other important factors in promoting positive motivation are physical comfort and cosmetic appeal. If the protector is unduly heavy, badly fitting, ill ventilated, or if it has poor optical qualities, it is unlikely to be worn. If it is ugly and does not allow individual choice amongst a selection of devices, compliance is also likely to be poor. Every opportunity must be used to provide flexibility in the choice of eye protection within the required standards.

Barenklau (21) points out that man functions best when not called upon to do anything that conflicts with normal behaviour. Eye protection is an unnatural state for those who like to work unrestricted or for those who do not usually wear spectacles. It is apparent that however necessary personal protective equipment might be, often a physical or mental obstacle has to be overcome. It is unreasonable to expect a man who spends long hours at his job to wear spectacles that

are uncomfortable, or in some other way make his working life miserable. The same level of comfort and acceptance should apply to properly fitted safety glasses as to ordinary spectacles (22).

The requirements of effective protection and wearer acceptance are, to some extent, mutually antagonistic. Eye protection for work often needs to sacrifice appearance for durability and comfort. For this reason, Wigglesworth (23) suggests that safety spectacles might be used in place of goggles or masks on the ground that spectacles are more likely to be worn and quotes Powell et al., "It is better to provide protection that is 80% effective, which people will wear, than protection which is 99% effective, that will not be worn because it is ugly." He argues that the best eye protection programmes include the **intermittent** use of high impact protectors for special, short term operations and duties, but the **day long use** of properly fitted, optically correct (and perhaps suitably attractive) spectacles with lenses of allyl resin or of toughened glass.

Although this approach may seem too compromising, it should be considered where protective devices presently available are unuseable because of unusual conditions, for example, for outdoor winter work in the oil industry or in winter logging operations.

Above all, compliance depends on the attitudes of managers and on the way eye safety programmes are introduced. The article by Barenklau (21) is recommended as useful reading in this area. Major points to consider are:

a. The employee must understand exactly what protective equipment each operation and area demands. Many companies include these specifications in the job description.
b. Staff and management alike should comply with the programme without exception.
c. The employees should be given the opportunity to select amongst a choice of eye protectors which comply with the standards of protection for a certain task. It is **absolutely**

essential that the device be individually fitted by trained personnel.

d. Eye protectors should always be maintained in stock. It is difficult to convince the employee that the device is important otherwise.
e. The stockroom should be clean and neat, with facilities for the disinfection and cleaning of eye protectors.
f. Worn out equipment should be replaced immediately because it is inefficient and may be unsafe.

The Relationship Between Accidents and Visual Performance

General Components

Responsibilities of industrial safety officers and nurses often include the examination of prospective employees. What particular defects should be sought out? Do inadequate vision characteristics contribute to the occurrence of general accidents? These questions are difficult and much of the information is based on reports of twenty or more years ago so that there is much uncertainty in the area.

There is some evidence that vision may be related to accident frequency (7, 24). Kephart and Tiffin (25) reported in 1950 that employees who passed "visual requirements" had fewer accidents than those who failed. Their findings are reproduced in Table IV. In each column in the table - those who passed visual requirements and those who failed visual requirements -the percentages given referred to those who had **less** than three accidents during the period of consideration. This peculiar separation indicates that those who passed visual requirements **may** have already had two accidents, a classification which clouds judgement on the issue. The difference between 65% and 57% for the overall group, although unlikely to have arisen by chance, appears surprisingly small. However, reports by Fletcher (7) who studied employees in a paper mill add some support to the thesis that "visual capacity" is related to the likelihood of having an accident.

Assessment of Visual Requirements of the Task

Many studies raise the question of how "visual requirements" for a job are determined. Again, the work on which opinion is based is now some twenty to thirty years old. Tiffin and Wirt (26) of the Purdue University Industrial Vision Institute used a purpose designed vision-screening machine – the Ortho-Rater – to study the relationship between individual vision characteristics, job classification and job performance. Job performance was measured in terms of quality and quantity of production, the ratings of supervisors, the number of accidents and so on, and from

TABLE IV
RESULTS OF VISUAL SKILLS TESTS IN RELATION TO INJURIES

Percentage of employees who had not over two injuries during the period of investigation among those who:

NO.	JOB	PASS VISUAL REQUIREMENTS	FAIL VISUAL REQUIREMENTS
59	Passenger Car Drivers	71	42
116	Mobile Equipment Operators	74	71
65	Machine Operators	67	50
15	Machine Operators	67	44
29	Sheet Metal Workers	58	41
105	Maintenance Men	81	75
63	City Bus Drivers	44	33
66	Intercity Bus Drivers	54	30
68	Supervisors	65	57
125	Machine Operators	56	32
102	Labourers	82	89
15	Skilled Tradesmen	45	33
828	All Groups	65	57

Reference: Kephart and Tiffin (25).

this information workers were classified as superior, average or inferior performers. In this way, for each of the job skills tested, limits were determined which defined the visual characteristics of the most successful performers and further limits were defined beyond which successful job performance was unlikely. Initially, visual performance profiles were established for each job but the similarity of profiles in certain jobs resulted in the designation of six job families, each with its own visual standards. The job families are shown in Table V and are summarized as:

1. Clerical and administrative
2. Vehicle operation
3. Close machine work and inspection
4. Machine operators
5. Mechanical and skilled trades
6. Labouring

The value of this approach is controversial. Although Kuhn (27) concluded that the Purdue visual skill test scores and job success were related, there is good reason to doubt the validity of the method.

For example, while those who pass a group of screening tests pass all the tests, those who fail may fail in only one of the groups - some may fail in visual acuity, others in ocular muscle balance, and yet others in binocular association. If the validity of the procedure is evaluated by comparing the industrial efficiency of those passing with those failing, a clinical evaluation of the importance of each separate item in the group of tests cannot be made (28).

Furthermore, the difference in visual acuity between groups is small and the definition of "normal" in muscle balance tests would be highly controversial in modern ocular motility terms as would the definition of normal depth perception.

In summary, the many variables involved in studying the relationship between job and visual capacity make study design extremely difficult, and it is doubtful whether studies using techniques available in the 1940's could be used as

criteria for job placement today. It cannot be concluded that a worker's success in a job is contingent upon his meeting the standards set for the six Purdue job families. The Purdue Visual Performance profiles must be recognized for what they are - a description of visual skills found amongst the greater number of successful performers on a particular job (28).

It is important that the limitations of this particular method of analysis should be understood because all of the major screening devices use it in the measurement of visual performance and the estimation of job success. Fig 2 is a typical vision screening form. The appropriate number or letter is checked off according to results measured on the vision screener. For each Purdue job family, there is a range of acceptable visual performance, giving a "visual profile" on the standard form as illustrated. If any of the workers' responses fell within the dark areas, this would indicate an unacceptable vision for the job in question. Of course, for different job families the template shape, or range of acceptable visual performances is different, and a result which might have been unacceptable for one job family may be acceptable for another.

An alternative approach is to study the job itself and from this to estimate the visual demands of the job. Such a "job vision analysis" contains the following factors (29):

1. Job description
2. Distance or distances to point of operation, fixed or changing
3. Size of the central working area, depth perception factors
4. Type of visual attention required: fixed or changing, casual or concentrated, detailed or gross
5. Motion of work: slow or rapid, rotation vertical or horizontal, fixed or intermittent
6. Colours to be perceived and discriminated
7. Illumination at workpoint and in surrounding area, direction of light, reflected or direct glare, brightness ratios

TABLE V

JOB CLASSIFICATIONS RESPECTING VISUAL PERFORMANCE

GROUP 1
Clerical and administrative (paralleling Profile No. 1)
1. Corrected distance acuity, 20/40 each eye
2. Corrected near acuity, 20/30 each eye
3. Normal muscle balance for near
4. Whether individual has normal distance muscle balance or normal depth perception is not of importance
5. Colour discrimination is not important unless individual is working with colour file cards or coloured materials

GROUP II
Vehicle operators (tractors, trucks, cranes, etc.) (paralleling Profile No. 2)
1. Corrected distance acuity, 20/30 each eye
2. Normal distance depth perception
3. Normal colour discrimination (if the individual uses coloured signals)
4. Normal muscle balance for distance
5. Degree of near acuity depends on whether individual needs to handle orders and make recordings (bifocals are contraindicated on crane operators)

GROUP III
Close machine work and inspectors (paralleling Profile No. 3)
1. Corrected 20/40 each eye distance acuity (actually degree of distance acuity important only for safety reasons and not for work requirements)
2. Corrected near acuity, 20/30 each eye (20/15 may be essential at times)
3. Normal near muscle balance
4. Normal colour discrimination if inspection includes colour evaluation
5. Distance muscle balances not important

GROUP IV
Machine operators (paralleling Profile No. 4)
1. Corrected distance acuity, 20/40 each eye
2. Corrected near acuity, 20/30 each eye
3. Normal depth perception
4. Normal muscle balance
5. Colour not of importance unless special requirement

GROUP V
Mechanical and skilled trades (paralleling Profile No. 5)
1. Corrected distance acuity, 20/30 each eye
2. Corrected near acuity, 20/25 each eye
3. Normal near muscle balance
4. Normal depth perception
5. Normal colour appreciation (if colours are used in operation)

GROUP VI
Labor (paralleling Profile No. 6)
1. Corrected distance acuity, 20/50 each eye (or 20/60, 20/40)
2. Degree of near acuity not important unless individual required to read orders; then should have corrected 20/30 each eye
3. Near muscle balance, not important
4. Distance muscle balance, not important
5. Depth perception, not important
6. Colour, not important (unless some special danger requires recognition of green-red signals)

8. Colour of light source and work area
9. Type of work surface: glossy or non-glossy, slightly or grossly uneven, angle of working surface, position of work in relation to normal level of eyes
10. Eye hazards: for example, flying objects, particles of dust, fumes, splashing chemicals or molten metal, airborne materials and radiation.
11. Type of eye protection required.

Having assessed the visual demands of the job, it still remains a matter of judgement to estimate the vision characteristics required to perform the component tasks, and the method. However, the difference in strategy is clear. Whereas the Purdue method associated vision characteristics with typical overall job classifications, the alternative approach studies the **components** of the job and estimates the visual demands of these components. The method is valuable because in the process of industrial change job characteristics are continually changing as discussed by Hofstetter (29).

The method of "Job Vision Analysis" is more costly because it requires each job to be analyzed separately rather than to be classified under general grouped headings. Can the added cost be justified? Individual analysis does allow examination of safety and protection requirements and of ergonomic aspects at the same time (see page 64). If time and cost considerations do not allow the full analysis, a simplified system is possible. Holmes (30) has published a "Guide to Occupational and Other Vision Needs" which outlines the visual demands of all the common occupations. With this as a basis, a few less extensive tests such as illumination levels, working distance and so on could be taken to ascertain the more unique properties of the task.

The Monocular Employee

A common concern in industry is that of monocular employees in jobs where depth perception and good peripheral fields of vision are required.

Recently handicapped individuals pose by far the greatest

FIGURE 2

Vision Tester

OCCUPATIONAL FORM RECORD OF

Name _____ No. _____

Address _____

_____ Date _____

Occupation _____ Dept. _____

Age ___ M ___ F ___ Tester _____ Clerk _____

Rx ___ None ___ Always ___ Bifocal ___ Near ___ Special ___ Safety ___

Last Exam. by Doctor _____ Change in Rx? Yes ☐ No ☐

Difficulty with Vision? Yes ☐ No ☐ Wearing Contact Lens Yes ☐ No ☐

Comments of Subject _____

Far Point (20 Ft.) Tests

Test No.	Target	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Both Eyes	T	R	R	L	T	B	L	R	L	B	R	B	T	R
2	Right	T	L	T	T	B	B	L	B	R	T	R	L	B	R
3	Left	L	R	L	B	R	T	T	B	R	T	B	R	T	L
	Snellen Equivalents	20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13
4	Stereo Depth	1 B	2 L	3 B	4 T	5 T	6 L	7 R	8 L	9 R					
5	Colour	A 12	B 5	C 26	D 6	E 16	F 0								
6	Vertical	1	2	3	4	5	6								
7	Lateral 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8	Demonstration Slide														
	Alternate														

14" ☐ Other

	Target	1	2	3	4	5	6	7	8	9	10	11	12	13	14
9	Both Eye	R	L	T	R	B	R	T	L	T	L	B	R	B	L
10	Right	T	B	T	B	R	T	R	L	B	L	R	R	L	T
11	Left	B	L	B	R	T	L	T	B	R	R	L	R	T	L
12	Lateral 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Alternate														

Perimeter Score Right _____ Left _____ Total _____

Referred: Yes ☐ No ☐

Professional Signature _____

Notified ☐ _____ 19___

Examined ☐ _____ 19___

problems since they have not yet learned to use monocular clues to depth perception. A person who has been monocular for some time has usually developed those clues which do not involve binocularity, for example, the apparent size of objects, overlap of contour and so on. In addition, the visual field of one good eye can be used more effectively by turning the head a little toward the blind side. Thus the limitation of job openings may be more those of statute or safety regulation than of true disability (31). Decisions should be made on an individual basis rather than ruling out all monocular individuals from particular jobs.

Vision Screening

Job vision analysis matches the visual demands of the job with the visual capacity of the worker. The visual demands of the job have been discussed in the preceding section. How is the visual capacity of the worker to be measured? Four systems are possible:

1. Full office examination by an optometrist or ophthalmologist
2. Modified examination at the work site by optometrist or ophthalmologist
3. Use of commercially available screening devices by other members of the health care team
4. Check of visual acuity by plant staff

Of these four, visual acuity tests examine only one of a range of functions of the eye. On the other hand visits to private practitioners are both costly and time consuming. The two practical methods are either to have site visits by a vision care professional or to have plant staff use screening devices.

When the vision care professional examines an employee he measures each of the characteristics required in the Job Vision Analysis. On the basis of the "Modified Clinical Examination" the measurements are compared with the estimated requirements and the employee is passed as suitable or unsuitable for the task. While it may be that some who are in fact suitable are thought by the examiner to be unsuitable and vice versa - that is that no examination is error free - it is to be expected that the

most useful judgements will be offered by the vision care professional.

What of the use of a screening device? Since neither the machine nor the operator can exercise judgement but must operate by rules, it is to be expected that more errors will arise i.e. that amongst those people passed by the screener as suitable some will in fact be unsuitable, and amongst those rejected as unsuitable there will be some who are in fact suitable for the job.

The performance of such screening systems is measured by the use of "Evaluative Indices" such as Sensitivity and Specificity by the estimation of false positives and false negatives. The calculation of evaluative indices is described in Appendix B.

Using evaluative indices Peters (32) has produced evidence which support the expectation that a vision care professional should produce the most useful results with the least errors.

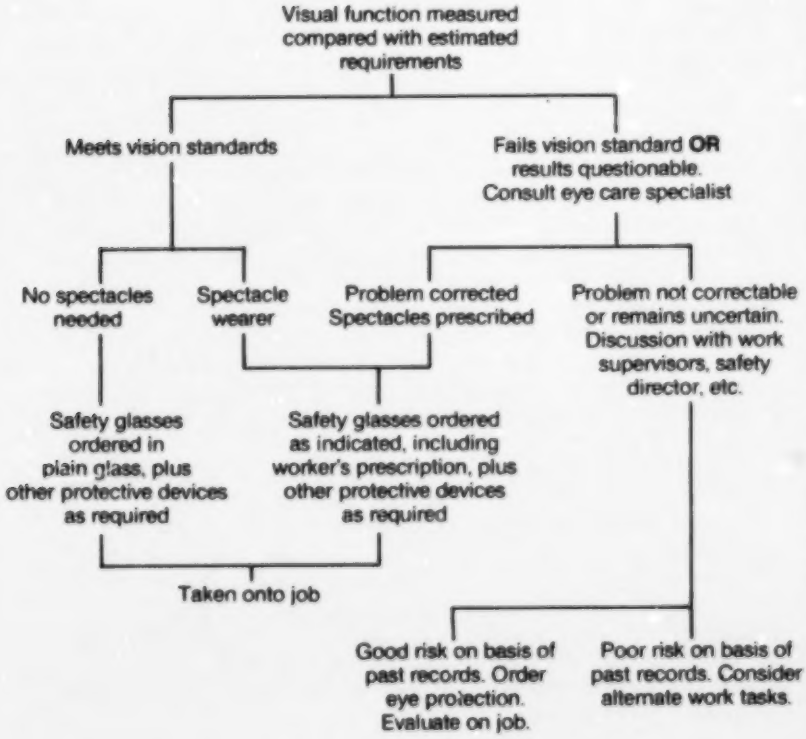
Which system is to be recommended in industry - the modified clinical examination or a screening device? In terms of reduced error the clinical examination is superior but there are contra-arguments. For example, professional services are more expensive, take more time and are more difficult to arrange. On the other hand the use of vision screeners by safety staff in industry is likey to lead to more errors. Those who fail visual requirements on the screener test can be referred for further assessment, but those who pass when in fact they should have failed - the "false negatives" - are not further screened but move on into the work force.

It is clear that there are many uncertainties in attempting to match an applicant's visual capacity with the job needs. However, provided that the Occupational Health Nurse or a trained Safety Officer will act as an integrator, participating in Job Vision Analyses and in the vision screening, the results can be reviewed with the professional consultant and the prospective worker advised and helped as indicated (see Fig. 3). We must also endeavour to improve industrial vision screening techniques through further research of existing and proposed procedures.

Most important, vision screening must always be done with the requirements of the job in mind. All too often screening is performed without an intelligent assessment of its strengths and limitations.

FIGURE 3

VISION SCREENING FOLLOW-UP ADAPTED FROM RENFRO (33)


Visual function measured compared with estimated requirements
Meets vision standards
Fails vision standard OR results questionable. Consult eye care specialist
No spectacles needed
Spectacle wearer
Problem corrected Spectacles prescribed
Problem not correctable or remains uncertain. Discussion with work supervisors, safety director, etc.
Safety glasses ordered in plain glass, plus other protective devices as required
Safety glasses ordered as indicated, including worker's prescription, plus other protective devices as required
Taken onto job
Good risk on basis of past records. Order eye protection. Evaluate on job.
Poor risk on basis of past records. Consider alternate work tasks.

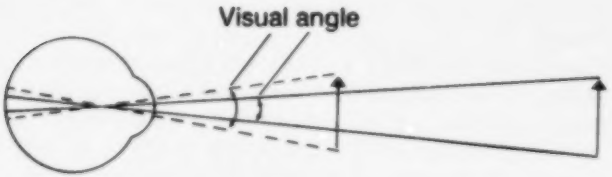
Factors Affecting Visual Performance

The visual capacity of a worker is determined both by characteristics of his eyes and by characteristics of the work task and working environment. In this final section, these two topics are dicussed, followed by a short summary of two related topics - the relation between fatigue and vision, and the modification of machines to make the work task easier.

Characteristics of the Eyes

Visual Acuity

The ability of the eye to discriminate objects is measured by the smallest size of object which can be identified at a set distance, usually six metres or twenty feet. At this distance, the object is said to subtend a "visual angle" at the eye, and this in turn determines the size of the image on the retina, as this diagram shows:



Object subtends angle at eye (visual angle) by size of object and its distance from eye.

A cumbersome but traditional system is used to express this "visual angle". An object which subtends five minutes of visual angle at the eye when situated at twenty feet gives a "normal" visual acuity of 20/20. If the object has to be twice as large to be seen at twenty feet, that is, an object which would subtend a visual angle of five minutes of arc at forty feet, then the visual acuity is said to be 20/40 and so on.

Visual acuity at near uses a similar principle, but involves the act of close focussing or "accommodation". The power of accommodation decreases with age so that people in their 40's or later usually need reading glasses, and their visual acuity should be recorded with reading glasses when worn.

Peripheral Vision (Visual Fields)

Visual acuity uses only a very small area of the retina close to the fixation point. The rest of the retina in each eye is used for peripheral vision which allows the detection of approaching objects and initiates a co-ordinated fixation movement of the eyes to look directly at the approaching object for its identification. The importance of peripheral vision in particular work tasks is obvious. Methods of measuring visual fields range from rough estimates, where the outer limits of the subject's field of vision are compared with the examiner's, to very precise instrumentation, but are not further discussed here.

Colour Vision

There are three different types of colour receptors in the eye containing three different colour-absorbing photopigments which are most sensitive to the three primary colours of red, green and blue. The whole range of colours seen is a result of the mixing of different degrees of stimulation of the three types of receptors.

People with abnormal colour vision have a relative or absolute deficiency of one or more of these three photoreceptors. Their disabilities range from slight difficulties in discriminating between red and green to a total absence of all colour vision. Colour vision abnormalities occur in about 8% of men and ½% of women.

Colour vision is usually screened by the standard Ishahara Colour Plates or by the modified Farnsworth 15-hue test. The Holmgren wool test, although outdated, is still used in some situations. The best test of all is, of course, whether the employee is able to do the job, and some industries set up specific tests based on this principle.

The suitability for employment of people with abnormal colour vision presents a very difficult problem since most

people with moderate colour vision abnormalities adapt so well to this handicap.

In considering colour vision handicaps, Cole (34) classifies tasks into four types:

a. **Comparative:** involving fine and detailed colour discrimination.

b. **Connotative:** involving recognition of colour codes.

c. **Denotative:** involving recognition of colour to mark out or identify.

d. **Aesthetic:** involving judgements of colour harmony and evocative qualities of colour.

For further discussion of this classification in relation to the employment of colour defective individuals, reference should be made to Cole's paper. It is best that each worker's case should be judged separately rather than that absolute exclusions should be applied.

Dark and Light Adaptation

The eye has the capacity to adapt to a very wide range of lighting levels from near darkness to full sunlight, far exceeding the range of any photographic film.

Vision in low illumination levels depends on the function of specific retinal receptors, the rods, which occupy most of the retina **except** for that small area on which visual acuity particularly depends, close to the central fixation point. This is evident when one attempts to see a dim star at night - gazing straight towards the star it may be impossible to see, but gazing just to one side of the star allows the rods to function and the star can be seen.

Three stages of retinal adaptation to light are recognized:

a. The PHOTOPIC state (day vision) in which the eye is adapted to bright light, visual acuity is best, and colour vision is present.

b. The SCOTOPIC state (night vision) in which the eye is adapted to low light, visual acuity is poor and colour vision is absent.

c. The MESOPIC state in which the eye shows some characteristics of both light adapted and dark adapted vision. In this range, small changes in lighting produce large changes in visual acuity. It corresponds roughly to the twilight time shortly after sunset.

There are best lighting levels for all work situations but of course most tasks require vision in the photopic range where maximum visual acuity and best colour discrimination occurs. The section on illumination will go further into this matter.

Eye Movement, Depth Perception and Working Distance

When the eyes change from viewing a near to viewing a distant object or vice versa, each eye must focus for the new distance and, at the same time, swing inward or outward to line up on the object. It is unusual for the alignment mechanism to be exactly adjusted, and the "fine tuning" of alignment depends on control exercised by the brain to fuse the images from the two eyes into a single and satisfying whole.

Errors in alignment which require fusion reflexes for correction are called "PHORIAS", and figure very largely in some industrial vision assessments, for example, in the aviation field.

Although limits to phorias are set in industrial classifications there is reason to doubt the merits of such criteria. The sensory system is enormously adaptable to often large phorias and many people with such phorias can work long hours without discomfort and with no symptoms. The area is controversial and requires further study, especially as it relates to the ability of the individual to work as effectively as possible in the work environment.

Characteristics of the Work Task and Environment

Illumination, Accidents, Visual Function and Job Performance

In many industrial **accidents** the cause has been attributed to inadequate illumination (35). The National Safety Council estimates that insufficient lighting was the sole cause of 5% of all industrial accidents, and poor illumination and fatigue played a part in 20% (36).

Ragsdale (37) lists three common lighting faults - insufficient light, shadows and glare. To this might be added risks due to stroboscopic effects, where light flickers in frequency with the alternating current source as in mercury vapour lamps. Turning wheels or moving machinery may appear to be stationary, and the danger is obvious.

There is considerable evidence relating **visual function** to illumination - for example, visual acuity declines with reducing illumination, and the decrease is greatest when contrast between the object of examination and its background is reduced.

Studies linking illumination to **job performance** are, however, necessarily more difficult because of the problems inherent in measuring performance and fatigue. Nevertheless, there can be little doubt that performance also declines with inadequate illumination and contrast (35, 36, 38.).

Lighting Standards

The environmental conditions for good visibility are generally recognized as:

a. Size
b. Time for perception
c. Contrast
d. Brightness

In most industrial settings, the first three tend to be fixed, while lighting is the factor which can be most easily changed and adapted.

The whole topic of illumination has a vast literature, much of it produced by the Illumination Engineering Society (40, 41, 42).

TABLE VII

RECOMMENDED MAXIMUM LUMINANCE RATIOS	ENVIRONMENTAL CLASSIFICATION		
	A	B	C
1. Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
2. Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
3. Between tasks and more remote darker surfaces	10 to 1	20 to 1	—
4. Between tasks and more remote lighter surfaces	1 to 10	1 to 20	—
5. Between luminaires (or windows, skylights, etc.) and surfaces adjacent to them.	20 to 1	—	—
6. Anywhere within normal field of view	40 to 1	—	—

- Luminance ratio control not practical

A - Interior areas where reflectances of entire space can be controlled in line with recommendations for optimum seeing conditions.

B - Areas where reflectances of immediate work area can be controlled, but control of remote surround is limited.

C - Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

Reference: American National Standards Institute, A11.1 - 1973 (40).

Standards are specified also in the Canada Standard Association C 92 - 1 "Industrial Lighting".

The proper quantity of illumination depends on the work that is being done. The degree of accuracy required, the fineness of detail to be observed, the colour and reflectance of the work task as well as of the immediate surroundings, all affect the illumination required. The attenuating effect of standard safety spectacles should be considered also. Finally, the quantity of illumination for best seeing may need to be increased somewhat for older people (43, 44).

The proper quality of illumination is also important. For example, not all light sources contribute to comfort, safety, aesthetics or ease of seeing. For example, excessive light produces glare and may cause shadows. Thus distribution of brightness and glare are two major factors in the quality of illumination (44).

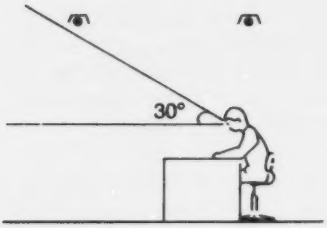
The proper distribution of illumination considers, for example, the ratios of luminance between the ceiling, walls and workbench tops on the one hand and of the work task on the other. Maximum permissible ratios have been recommended, and to achieve these standards the reflectance of room surfaces and equipment should be listed (40). Table VII illustrates these recommendations.

Descriptions of Lighting Systems

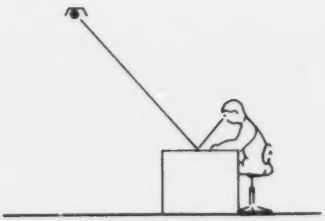
Basic guidelines for the placement of lighting sources are reviewed by Grandjean (36).

a. No light source should be in the direct view of the worker.
b. To achieve this, the angle between the horizontal line of sight and the line from the eye to the light source must be more than 30 degrees (Fig. 4a). In rooms where this cannot be avoided, the luminaires must be screened on the sides.
c. Unscreened luminaires should not be used in work rooms.
d. To avoid glare from reflection the work should be positioned so that the most frequently used lines of sight do not coincide with reflected light (Fig. 4b) and

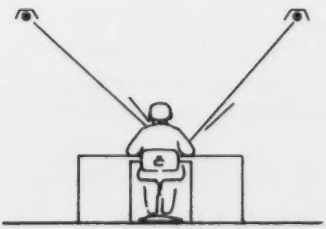
FIGURE 4



a.
The angle between the horizontal line of sight and that from the eye to the light source should be greater than thirty degrees.



b.
Unsuitable positioning of the light source in relation to the work piece. Reflected light coincides with the line of sight so that direct glare through reflection can occur.



c.
Suitable positioning of lights. Reflected light sources set to eliminate glare through reflection.

so that no reflection area with contrast greater than 1:10 lies within the field of vision (Fig. 4c).

Fig. 5 shows five situations with varying placements of supplementary lighting Examples b & d show light reflecting into the eyes, whereas the positioning of a, c & e would be acceptable.

Descriptions of lighting systems and the types of light source to use are provided in many publications of the Illuminating Engineering Society. Systems should be designed to provide the desired illumination uniformly over the entire area. There may be one or more areas where the tasks to be performed require a greater quantity or a different quality of light. In these areas, additional luminaires may be installed.

A report in 1972 indicated that nearly 90% of the lighting in Canadian industrial plants was below the minimum standards of the Illuminating Engineering Society (45). In addition, good lighting systems often become inadequate over time because of aging and uncleanliness. In the worst case, if lamps were cleaned only once a year and not replaced for three years, only 51% of the initial illuminance would remain (41). Increased productivity would almost certainly be greater than the cost of bi-annual cleaning of the lamps. Similar loss of lighting efficiency occurs from dirt on room surfaces due to loss of reflectance.

Torkia (39) describes the effect of a relighting programme in a 20,000 square foot machine shop. The plant employed 80 people. The cost of the system was $20,000 which amortized over ten years amounted to five cents per hour, per employee. Morale was noticably increased, minor accidents were reduced by 50% and productivity increased 10%. The productivity increase was equivalent to 35 cents per hour, confirming the cost benefit of the programme.

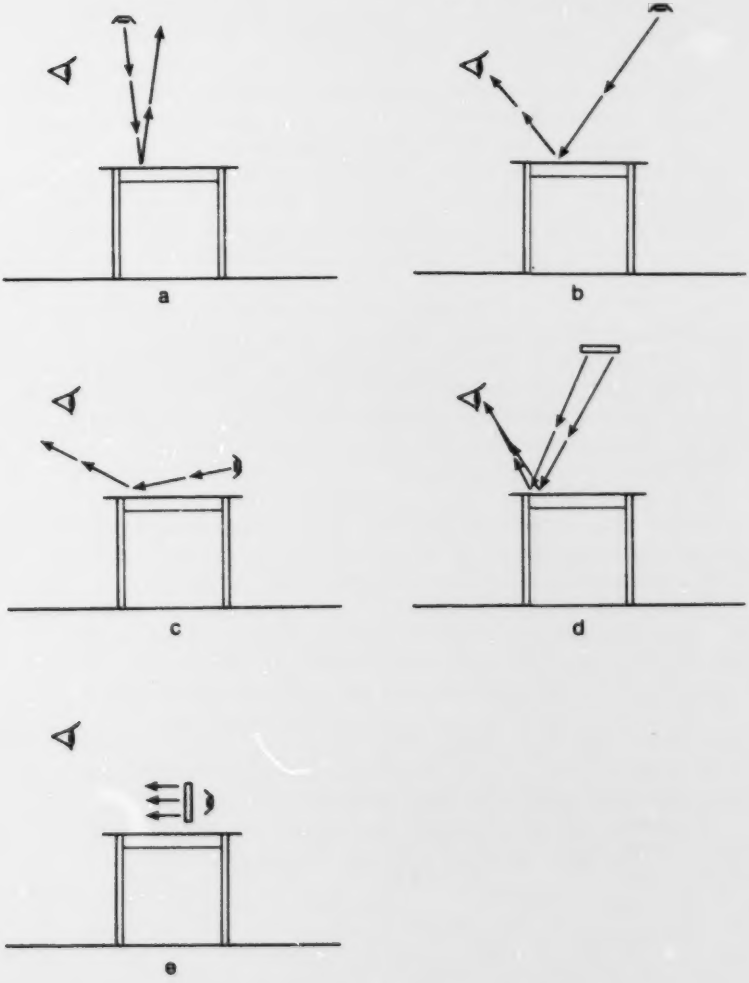
Thus the benefits of better illumination are better production, fewer accidents, better morale and better motivation.

FIGURE 5

PLACEMENT OF SUPPLEMENTARY LUMINAIRES

ACCEPTABLE

UNACCEPTABLE



Glare

Glare, closely related to brightness and illumination, has received considerable attention recently. It is defined as "the discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings" (42).

Glare is called DIRECT when it arises from a source of lighting within the field of view, and INDIRECT when it is caused by bright reflections from shiny ceilings, walls, desk tops, materials and machines within the field of view. Whether direct or indirect, the disabling effects become greater as the glare source approaches the line of sight (Fig. 6).

From the physiological point of view glare arises in three ways: where the contrast between two objects in the field of vision is too great (RELATIVE GLARE); where there is such high luminosity in the visual field that adaptation becomes impossible (ABSOLUTE GLARE); and where the eye is dazzled before there has been time to adapt to a new level of illumination (ADAPTIVE GLARE).

However, in the industrial setting, glare is better classified according to whether it is DISABLING or produces only DISCOMFORT and strain (46). This classification is as follows:

DISABLING GLARE may be of three types -

i) **Relative**

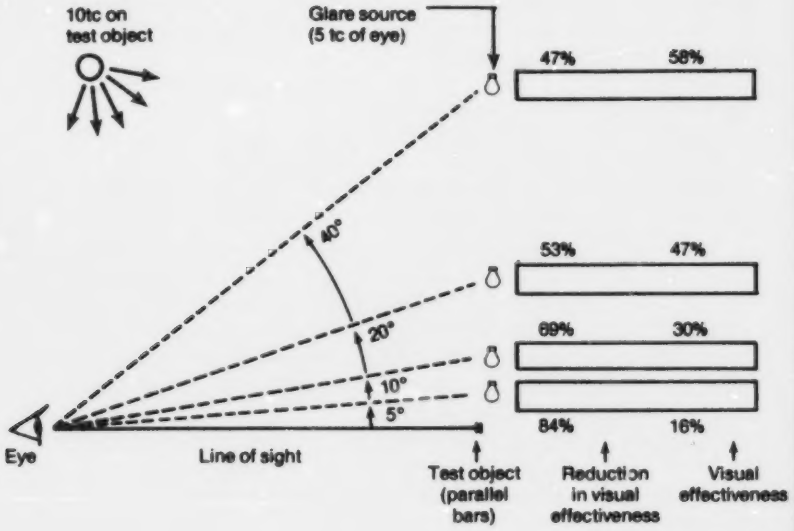
Because of excessive contrast between a bright and a darker area, there is loss of detail in the darker area with impairment of vision (46). The difficulty of seeing the walls of an unlit corridor against the glare from a window at its end illustrates this glare.

ii) **Veiling**

This type of glare occurs where dirty or slightly misted goggles scatters a uniform "film" of light from a single bright source.

Contrast in the retinal image is reduced and visual acuity decreases.

FIGURE 6



Effects of direct glare on visual effectiveness. The effects of glare become worse as the glare source gets closer to the line of sight. (Reference: McCormick (38)).

iii) **Sensory Overload**

This type of glare occurs as a result of exposure to levels of luminance far beyond those to which the eye is adapted (47). The dazzle produced by an oncoming car headlight at night provides an example.

DISCOMFORT GLARE, while sometimes causing immediate disability, over a period of time can cause eyestrain, headache and fatigue. Its cause is the same as disabling glare - excessive contrast between an object and its background (46).

The ability to perform efficiently in the presence of a bright light source is called glare resistance. Generally, the better the optical system of the eye, the better its glare resistance (48). Resistance commonly increases when a refractive error is corrected by spectacles, indicating a relationship between glare resistance and image quality.

Visual discomfort from glare is a major concern when designing light systems (38). The Illuminating Engineering Society has adopted a standard procedure for computing discomfort glare ratings (DGR) and Table VIII gives a short list of recommendations for the reduction of glare.

Fatigue

In estimating the effect of illumination and glare on visual efficiency, one measure of visual efficiency involves the concept of **fatigue**, an ill-defined term used to denote the effect of many different conditions all of which cause a reduction of work capacity (48).

Fatigue has subjective and objective components. Subjective fatigue results in changes in feelings and awareness and precedes the appearance of objective fatigue which results in performance changes (49). When objective change appears, the earliest sign is usually an increased variability in performance. Later there is a complex trade-off between speed and accuracy, errors increasing suddenly and erratically with speed being subject to apparently random fluctuations.

Physiological fatigue, occurring in its most extreme form

TABLE VIII

THE REDUCTION OF GLARE

To Reduce Direct Glare

1) Select luminaires with low discomfort glare ratings.
2) Reduce the luminance of the light sources (for example, by using several low-intensity luminaires instead of a few very bright ones).
3) Position luminaires as far from line of sight as is feasible.
4) Increase the luminance of the area around any glare source, so that the luminance (brightness) ratio is less.
5) Use light shields, hoods, and visors where glare source cannot be reduced.

To Reduce Reflected Glare

1) Keep luminance level of luminaires as low as is feasible
2) Provide good level of general illumination (such as with many small light sources and use of indirect lights).
3) Use diffuse light, indirect light, baffles, window shade, etc.
4) Position light source or work area so reflected light will not be directed toward the eyes.
5) Use surfaces that diffuse light, such as flat paint, nongloss paper, and crinkled finish on office machines; avoid bright metal, glass, glossy paper, etc.

Reference: McCormick (38).

in runners at the finish of a marathon, relates to energy supplies, energy reserves and the clearance of products of metabolism. However, when a performance decrement is noted in the industrial setting it is almost certainly psychological rather than physiological in origin and is enormously variable, intimately associated with morale, motivation, monotony and general health (49).

Monotonous surroundings or a boring task favour the onset of fatigue (50). Brightly coloured, well-illuminated surroundings and tasks well matched to worker capabilities should reduce fatigue.

"Visual fatigue" is another rather loosely defined concept. It is expressed in a feeling of strain in the eyes, which may occur in people with normal visual function if they attempt difficult visual tasks, or in people with certain visual abnormalities performing normal tasks. For example, improperly corrected refractive errors, under-corrected presbyopia (need of reading glasses) or abnormal binocular association may all play their part.

The relationship between visual strain and general, rather than visual, fatigue may be important although it is ill-defined. Grandjean (50) considers that fatigue from visual stress can result in production losses, lowered quality of work, increased frequency of errors, or an increased accident rate.

Although the concept of fatigue is widely discussed, there is very little quantitative data to support any hypothesis regarding stress and ocular mechanisms. This is because the subjective feeling of fatigue is so variable, and is almost impossible to relate to visual performance functions. The most important thing that can be said is that all workers should have visual function operating at its best level by use of spectacles and any other means to remove this one factor from the accident inducing environment.

Ergonomics

In man-machine interactions, five areas present for study (49). These are:

1. Machine information presentation and display
2. Information reception by worker
3. Information processing and decision making by the worker
4. Initiation of appropriate response by worker
5. Machine control and manipulation.

The study of ergonomics concentrates particularly on the relationship between numbers 1 and 2 and between numbers 4 and 5 above, that is, the man-machine interface, taking particular account of the limitations of the human machine. The function of ergonomics is to place the worker in an environment which maximizes those factors leading to better performance and minimizes those factors which lead to fatigue and inefficiency. its importance in relation to industrial safety is obvious.

Investigation in this area is made difficult because of the enormous adaptability of man, such that he will adjust his patterns of work and response to fit the machine, often without recognizing that he is doing so. Clearly, both work efficiency and work safety are affected by the outcomes of ergonomic studies.

Examples of the classification and analysis of the man-machine interface follow:

Information Display/Reception

The majority of information received by workers in a man-machine system is visual. Information visual displays are three basic types (51):

a. Quantitative display used to present information on quantities or measurement.
b. Qualitative display used to present information on states or conditions e.g. high, average, low
c. Check display used to indicate whether a particular condition exists e.g. on or off shown by green or red lights.

In designing such displays, the following principles should be considered: **compatibility** - the motion of the display should be compatible with the motion of the machine and its controls; **arrangement** - displays should be grouped according to the relationships of the information presented; and **coding** - the display should be marked or coded for the specific purpose served - should be applied. These principles are classified as encoding problems (49). The information display should match the pattern in which the worker thinks about his job, eliminating the need for recoding of information by the operator before it is useful.

Response/Machine Control

Operation of a machine, like the reception of data, depends heavily on vision. Just as principles exist for the design of displays, so do principles exist for the design of controls to facilitate operation and to eliminate error.

Controls are of two basic designs - pressure controls on which a force is exerted and displacement controls on which a movement is made. In control design, the controls must be matched to the muscular strength of the operator and to his motor skills and timing limitations (49). With respect to the motor skills there are two major considerations: compatibility of controls with display and machine movement and coding of controls for shape, texture, location and colour.

For those involved in industrial safety, several reference texts are available. (2, 3, 11). It is clear, however, that the weakness of man-machine systems can often be traced to inadequate interface design.

Summary of Factors Affecting Visual Performance

"Visual Performance" results from the interaction of vision, illumination, glare, fatigue and the design of man/machine interfaces. Each of these components is the composite of many different sub-units, and there is little doubt that proper attention to all factors will result in better productivity and a safe working environment for the prevention of both general and ocular accidents. Although it is not to be expected that

Industrial Nurses and Safety Officers will be familiar with details in each area, a general over-view of the factors, and a knowledge of where information is available, can only improve the quality and usefulness of their work.

Appendices

APPENDIX A

Eye Protectors Identification List

An Occupational Safety Guide to assist users, inspectors and purchasers in the identification of eye protectors claimed by the manufacturers to meet the requirements of the CSA Standard on Eye Protectors, Z 94.3 - 1969.

Canada Safety Council 1765 St. Laurent Blvd.
Ottawa, Ontario K1G 3V4 3rd Edition, 1980

Foreword

A National Seminar on Eye Protection was held in Toronto on 10th February 1975 for the purpose of determining what further steps need to be taken to reduce eye injuries on-the-job.

During a discussion of the CSA Standard on Eye Protectors Z 94.3 - 1969, the question of identification of eye protectors that could meet this standard was raised. It was considered important for purchasers, inspectors and users of eye protection equipment to know whether it could meet this standard, observing a CSA Certification Program does not exist.

The Canada Safety Council was asked to prepare a list of designations (monograms, logos, company names, etc.) which are placed on this equipment by manufacturers, and to distribute this list across Canada for the benefit of purchasers.

The following list represents the results of the survey of manufacturers & distributors of safety glasses in Canada conducted by the Canada Safety Council, Occupational Section. It should be noted that the markings indicated are usually those of the manufacturer rather than the distributor or supplier from whom they may be purchased. Hence, all suppliers are not included in this list.

The list should not be construed as confirmation by the Canada Safety Council or the Canadian Standards Association that the products do in fact meet the requirements of CSA Standard Z 94.3 - 1969 but simply that the manufacturers claim these products meet that standard.

COMPANY	LENS	FRAMES	
Allsafe Products of Canada (American Allsafe Co. Inc.)	Allsafe	Allsafe ® "201" "211" & "203" "202"	(top centre) (in model no. on box) Meets class 3(a) (in model no. on box) Meets class 3(b) & 3(a) (in model no. on box) meets class 3(b) & 3(a) except has no ventilation for extreme dust or splash hazards short duration usage.
American Safety Equip. Corp.	A.S.	 B.I.	(on front) (inside temple)
AOCO Limited (American Optical Corp.)	A O or A_O	A O or A_O	(on front) (excluding metal frames)
Bausch & Lomb Optical Co. Ltd.	B L	+	(on front) excluding metal frames which are marked Bausch & Lomb Safety.
Belco Safety Products Ltd.	A.S. or B or O	+ -	(on front) (on temples)
H.L. Bouton Co. Ltd.	B Bouton (on flexible frame "Softsides" goggles only)	BB Bouton Bouton	(front & temples) (on temples) (on flexible frame "Softsides" goggles only)
Essilor Canada Ltee Ltd.	O.M.	"Essilor Protection" on inside of right temple.	
Fendall Company	f	f Fendall	(on front) (on temples)

COMPANY	LENS	FRAMES
Fibre-Metal (Canada) Ltd.	Fibre-Metal FM (the use of H and/or a number indicates heat-treating and the shade)	Fibre- Metal or FM
Gentex Corporation	(omni - Gard Poly-Carbonate)	
Glendale Optical Co. Ltd.	GO	GO (inside left)
Levitt - Safety Limited	LS	
MSA Canada	MSA or MSA	MSA (on temples) or MSA (on temples)
Norton Safety Products Ltd. & Produits de sécurité Norton (Québec) Ltée.	N	Norton (inside right front and inside temples)
Ohio Goggle Co.	OG	None
Parmelee Limited	P (upper outside on prescription)	(front)
or	P (upper centre on non-prescription)	P1 plus the size (inside frame) P1 plus the size (inside temples) + (outside temples near hinge)
Pennsylvania Optical	B	

COMPANY		LENS		FRAMES
Safety Supply Co.	or			
		H (in corner of lens) (Hardex on glass lens & Hardlite on plastic lens)	or or	S.S. Co. Safety Supply Co.
Sellstrom		SMM (med. green)	S	(goggle front & temple shield)
	or	SMD (dark green)		
	or	SMXD (extra dark green)	or	Sellstrom (on temples)
	or	SM (clear, grey or clear polycarb)		and on 880, 881, 882, 890, 892, 650, etc. goggles.
	or	LEA and shade		
	or	LWP and shade	or	SM (on 700 series fronts)
	or	H-PYA and shade (plate ident.)		
	or	S (on 880 goggle lenses)		
	or	PWP and shade (plate ident.)		
Titmus Optical Inc.				(on frames & temples)
Uvex Winter Optical, Inc. (distributed by Cadillac Plastic)		Although no monograms are used by Uvex, this firm claims all its products meet CSA Z 94.3.		
Watchemoket Optical Co Inc.		E.S.	E.S.	(inside right)
Welsh Manufacturing Co. (Norton)		W_M	Welsh W_M	(inside right temple) (inside left front)
Willson Products	or	W IBW	W	

APPENDIX B

Evaluative Indices

No system of measurement is error free. This is particularly true in complex assessments of several factors on which suitable/not suitable decisions are based. In eye examinations for industry, it is to be expected that some prospective workers will be rejected when they are in fact suitable, for a job and some will be accepted when they are in fact unsuitable.

The likelihood of classification errors of this kind is best expressed in **Evaluative Indices**. The indices are usually derived as follows: A sample group of individuals known to be unsuitable is subjected to the test. A proportion of the group is thought to be unsuitable and the remainder is falsely classified as suitable. A sample group of individuals known to be suitable is subjected to the test, and a similar analysis is performed. Note that the analysis does not require that a whole population be tested, but only that sample groups with known characteristics be examined.
It is now possible to construct the following table.

		KNOWN CONDITION	
		+	-
TEST RESULT	+	a	b
	-	c	d

These calculations are:
1. SENSITIVITY: percent of people who actually have a vision problem and who are detected by the test.

$$= \frac{a}{a + c} \times 100$$

If we were now applying this test in a population where the prevalence of the particular vision problem was, for example, 40 per 1,000 screened, we would expect to detect only 40 × Sensitivity % of that group. The remainder of those with a vision problem would go undetected.

2. SPECIFICITY: percent of people who actually have no vision problem who are excluded by the test.

$$= \frac{d}{b + d} \times 100$$

Applying the test to the same population, we would expect to detect 960 × Specificity % as free from the defect. This means that the remainder of this group would be classified in error as having a vision defect.

In an experiment reported by Peters (32), the results of a Modified Clinical Examination were compared with the results from a commercially available screening machine.

For the screener, Sensitivity was 53% and Specificity was 93%. This means that 47% would be passed into the work force who were in fact not suitable, whereas only 7% would be falsely rejected.

The results from a professional Modified Clinical Examination gave Sensitivity 100% and Specificity 99%. Clearly, the modified clinical examination is far superior.

Peters results provide a good example of the use of such indices, but are not beyond criticism. It is evident that he did not **select** two separate groups of equal size on whom to apply the test, one group having the vision anomaly and the other group having none. Had he done so, the size of his "anomaly present" group would have been much larger. This defect in experimental design may well have contributed to the poor sensitivity of the vision screener.

APPENDIX C

Contact Lenses in Industry

Contact lenses are divided into two basic designs:

Hard Plastic Lenses

These are rigid plastic lenses smaller in diameter than the cornea ranging in size from about 6 - 9 mm. They may be coloured, and are concave in shape to fit the curvature of the cornea.

Soft Polymer Lenses

These are flexible lenses made of hydrophilic polymer compound. Lenses vary in size from about 11 - 16 mm, in water content from 25% - 85%, and in most cases, conform to the shape of the cornea.

Both hard and soft contact lenses must be stored in special solutions which ensure their sterility and hydration. Contact lens wearers must be scrupulously clean in the handling of their lenses. Improper handling can lead to bacterial contamination, stains, tears and pits in the lenses and consequent risk to damage to the eye.

Various authors (52, 53, 54, 55) have rejected the use of contact lenses in industry for the following reasons:

1. In dusty industrial environments, particles may be trapped behind the lens and scratch the cornea. Particles may also scratch or soil lenses.
2. Chemical splashed in the eyes of contact lens wearers are more difficult to flush out of the eye, and the soft contact may bind chemicals in their polymer structure, providing a source of continuing irritation if the lens is not removed from the eye.
3. Chemical fumes may damage contact lenses and irritate the eyes.
4. Electric (arc) flashes may cause the thin layer of tears between the contact lens and the corneal epithelium to break up and the contact lens becomes stuck to the corneal epithelium. Upon removal of the lens, corneal epithelium is taken with it leaving a corneal abrasion.
5. Accidental displacement or loss of a contact lens may occur without warning, causing a sudden change of vision, excessive tearing, light sensitivity and involuntary lid blinking.

6. When contact lenses are removed and spectacles are worn, a period of blurred vision may follow (spectacle blur). Should an employee by choice or need remove his contacts, he could then have less than best vision for a period of time and could become a safety hazard.
7. Contact lenses may produce medico-legal problems. Undetected contact lens wearers at initial screening would show a visual acuity which is far better than their true "uncorrected" acuity. An apparent reduction of vision from an accident might result in a generous compensation award unless medical records substantiate the true state of uncorrected vision.
8. A final argument is that often contact lenses are very hard to take out, especially in an emergency situation where no medical service is quickly available.

These arguments are not conclusive. Indeed, the literature reviewed shows a remarkable lack of evidence to support them.

A paper by Rengstorff and Black (56) reports on an extensive study of injuries to contact lens wearers. They conclude that in cases of physical trauma, contact lenses provide better protection than spectacle lenses. Jackson (57) reports that when a contact lens is worn blows to the eye tend to be distributed over a larger area. The lens has either caused no damage to the eye or actually acted as a mechanical protector. This suggests greater protection, not greater danger.

Rengstorff and Black (56) show through individual case reports and animal experiments that contact lenses provided protection rather than causing injury in chemical accidents. A study by Guthrie and Seitz (58) showed that rabbit eyes fitted with hard contact lenses had less damage due to chemical injuries than control eyes. They concluded that the protective effect of contact lenses appear to be a function of time although no study was made of soft contact lenses which pose special problems because they bind to chemical substances. From this evidence, it is difficult to accept generalizations that contact lenses are unsafe when working with chemicals.

If contact lenses are allowed in industry, additional considerations should add perspective to the problem.

1. The contact lens wearer must be identified at the pre-employment examination. Visual acuity should be taken through spectacles, contact lenses and with the naked eye. Where contact lenses are permitted, the wearer of contact lenses should be identified in case of emergency.
2. The fact that occupational health nurses, safety personnel and other health workers are unfamiliar with contact lens removal is not an indictment of contact lenses but rather an indication of the need for training (See point 8 discussed previously.)
3. There are certain adverse environments where a worker might be exposed to dusts, chemicals, and fumes. It would therefore be advisable not to wear contact lenses. Occupational health personnel have the responsibility for describing these areas for job classification and safety restrictions.
4. Since contact lenses only cover a small part of the front of eye, the wearer must use additional industrial safety spectacles approved for the particular job and hazard. In some situations, vented goggles should be considered instead of safety glasses.
5. It is advisable for every contact lens wearer to have a pair of prescription industrial safety glasses for emergencies or illness when contacts cannot be worn.

In summary, the use of contact lenses by industrial workers can be neither approved nor condemned on a general basis. The individual's use of the contact lenses should be carefully evaluated based upon a thorough study of the hazards of the job, the ocular status of the individual and the visual requirements of his occupation.

APPENDIX D

Colour In Industry

Colour has become a very important factor in industrial design. Standard colours are used for safety and identification purposes. Colour contrasts are used to aid in the identification of machine parts to increase both safety and performance. Finally, the psychological effects of colour may be used to produce a comfortable and productive atmosphere for the worker.

Safety and Identification

Colour coding of equipment, pipes and signs has become essential in industry. While never used as a substitute for good safety measures and mechanical safeguards, standard colours identify specific hazards and noteworthy areas in the plant. Colour coding standards and colour characteristics - hue, saturation, brightness - are established by the American National Standards Institute in three areas.

Colour Coding of Equipment (A.N.S.I. Z 53.1)

i) **Red** identifies fire protection equipment, danger, and emergency stops on machines.

ii) **Yellow** is the standard for marking hazards that may result in accidents from slipping, falling, striking against, etc.; flammable liquid storage cabinets; a band on red safety cans; and machinery for handling equipment such as lift trucks and gantry containers. Black stripes or "checker board" patterns can be used.

iii) **Green** designates the location of first aid and safety equipment (other than fire fighting equipment).

iv) **Black and White** and their combinations in stripes or checks are used for housekeeping and traffic markings. They are also permitted as contrast colours.

v) **Orange** is the standard colour to highlight dangerous parts of machines or energized equipment, such as exposed edges of cutting devices, the inside of moveable guards and enclosure doors, and transmission guards.

vi) **Blue** is used on information signs and bulletin boards not of safety nature.

vii) **Reddish-Purple** identifies radiation hazards.

Colour coding of Pipelines (A.N.S.I. 13.1)

Red	Fire Protection (Water) Lines
Yellow	Dangerous Substance
Green	Safe Materials
Bright Blue	Protective Material

Colour Coding of Accident Prevention Signs (A.N.S.I. Z 35.1)
The signs are designed in such a way that normal colour-vision is not essential for interpretation. Thus, the colour coding is an aid in identification. In addition, gas cylinders are identified by colour.

Creation of Contrasts

Contrast is directly related to visual acuity. As contrast between objects increases, so does the ability of the eye to resolve the objects. Colour contrast is best when complementary colours are used, as the greatest "colour difference" can be obtained. Colour contrast, for instance, makes machines parts more visible, shortens the time needed for perception, and reduces visual search time. In this way it serves both a safety and a performance function.

Psychological Effects of Colour

It is well recognized how colours affect moods and feelings. These effects have been used in industry to aid in the comfort, and increase the productivity of workers. Efforts are made to use attractive colours, suited to the available space, lighting, and the type of job. The following Table describes how colours affect our perception of the environment. The manner in which space and size can be apparently altered is particularly interesting.

In conclusion, colour can play a crucial role in the industrial setting. It is recommended that information be obtained from the American National Standards Institute regarding the use of colours for safety. Further information on the environmental and psychological factors of colour can be obtained from a vision care professional and/or design consultants in colour.

PSYCHOLOGICAL EFFECT OF COLOURS

Influence of colour on	Effect
Size	Green and blue objects seem larger than red and yellow ones.
Space	Green and blue surfaces appear to recede, red and yellow surfaces appear to come forward.
Plasticity	Short wave colours (violet, blue, green) make an object look flat, long wave colours (yellow, red) create an impression of "plasticity".
Temperature	Red and yellow are "warm", blue and green "cold".
Hardness	Red, white, yellow are "hard", green, black, blue are "soft".
Weight	Bright colours make objects look lighter in weight.

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